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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2002952062 for a patent by D.WILSON INVESTMENTS PTY.LTD., THE AUSTRALIAN STEEL COMPANY (OPERATIONS) PTY.LTD. and FERRO CARBON TECHNOLOGY PTY.LTD. as filed on 15 October 2002.



WITNESS my hand this
Thirtieth day of October 2003

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PROVISIONAL SPECIFICATION

Invention Title: PROCESS AND APPARATUS FOR
 EXTRACTING ZINC

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The invention is described in the following statement:

PROCESS AND APPARATUS FOR EXTRACTING ZINC

This invention relates to a process for the extraction of zinc from a zinc containing material, and to an apparatus for carrying out the process. The invention is particularly suitable for the extraction of zinc, from electric arc furnace
5 (EAF) dust. The following discussion will focus on extraction of zinc from EAF dust, however it is to be clearly understood that the invention is not limited to such an application.

Electric arc furnace (EAF) technology is becoming an increasingly more important means for steel production world-wide. EAF technology, however,
10 suffers from the disadvantage of producing as a by-product, large quantities of EAF dust. Approximately 15 to 20 kg of EAF dust is formed per tonne of steel, meaning that millions of tonnes of EAF dust are produced annually world-wide. It is considered a toxic waste and its safe disposal is accordingly problematic. Moreover, given that EAF dust includes as major components : iron, zinc, lead
15 and other elements of economic significance, it is a potentially valuable resource yet to be adequately commercially exploited.

There is clearly a need for an effective and safe means for dealing with EAF dust which also takes advantage of its potential value.

According to the present invention, there is provided a process for
20 extraction of zinc from a zinc oxide containing material, said process including:

- (a) mixing a carbonaceous material with said zinc oxide containing material to produce a cohesive mass;
- (b) compacting the cohesive mass to produce a composite body;
- (c) heating the composite body in a reducing atmosphere at a
25 temperature and for a time sufficient to form a reductant from said carbonaceous material to reduce a predetermined amount of the zinc oxide to zinc vapour;

(d) collecting said zinc vapour and cooling it to form zinc metal.

The present invention also provides an apparatus for carrying out the zinc extraction process. The apparatus comprises:

a furnace chamber for receiving composite bodies including a zinc oxide
5 containing material and a carbonaceous material;

an outlet in a wall of said furnace chamber; and

a condenser communicating with said furnace chamber via said outlet
wherein, in use, zinc vapour produced in said furnace chamber passes through
said outlet and into said condenser where it condenses to form zinc.

10 In the zinc extraction process of the present invention, the zinc oxide
containing material is typically electric arc furnace (EAF) dust, although other zinc
containing materials, such as zinc plant residues may be used. As previously
mentioned, EAF dust is a waste by-product of steel production via EAF
technology and results from vaporisation of volatile metals, particularly zinc and
15 lead, which are subsequently oxidised and extracted as a fine dust. EAF dust
contains largely a mixture of oxides, composite iron oxides and chlorides and may
include a number of different elements, chiefly iron, zinc, calcium, silicon, lead,
copper, manganese, chromium and cadmium.

While the present invention is primarily concerned with zinc extraction from
20 zinc containing material, it can also extend to extraction of other metals present in
the zinc containing material. The oxides of those other metals should be
reducible by reductants derived from carbonaceous material. Where the zinc
containing material is EAF dust, other metals which may also be extracted include
iron, lead and manganese.

Accordingly, one preferred embodiment of the invention is concerned with a process for extraction of metals including zinc, iron and lead from their respective metal oxides in EAF dust, the process including the steps:

- 5 (a) mixing a carbonaceous material with said EAF dust to produce a cohesive mass;
- (b) compacting the cohesive mass to produce a composite body;
- (c) heating the composite body in a reducing atmosphere at a temperature and for a time sufficient to form a reductant from said carbonaceous material to reduce a predetermined amount of said metal oxides to said metals, said
10 zinc oxide being reduced to zinc vapour;
- (d) collecting said zinc vapour and cooling it to form zinc metal;
- (e) further heating the reduced composite pellets to a temperature sufficient to effect melting of the remaining metals, including iron and lead, in the reduced pellets; and
- 15 (f) separating and cooling the respective molten metals.

The carbonaceous material used in the inventive process preferably has a high surface area and small grain size in order to maximise the chemical reactivity of the reductant.

Preferred carbonaceous materials are finely divided brown coal or peat
20 because of their cellular structure resulting in high chemical reactivity. Using low rank coal or peat instead of higher rank coal is advantageous economically, due to the lower cost of low rank coal or peat. Brown coal or peat also have desirable physical properties, in particular their ability to plasticise under mechanical shear which enables the production of cohesive pellets formed by extrusion. Without
25 wishing to be limited to a particular mechanism of formation, it is believed that shearing causes attritioning of the brown coal or peat particles resulting in

conversion of finely dispersed water in the structure to a bulk liquid phase, and polymerisation of phenolic rings present in the brown coal causing the coal or peat to become wet and plastic. Shearing also produces large numbers and areas of freshly cleaved coal surfaces, thereby maximising the physical association of coal/peat particles with metal oxide particles which in turn enhances the rate of the reduction reaction.

Alternatively, the carbonaceous material may comprise a higher rank coal or some other finely divided active carbon-source material, such as sawdust. In this case, it may be necessary to add a binder and/or water to the mixture of zinc oxide containing material and carbonaceous material so as to produce a cohesive mass able to be formed into pellets, such as by extrusion.

Whatever the type of carbonaceous material, it may be necessary to add additional water to the mixture of step (a) so as to produce the desired consistency of the plastic mass.

Preferably, the composite body is in the form of a pellet. More preferably, the pellet is formed by extrusion of the cohesive mass.

The relative quantities of the carbonaceous material and zinc oxide containing material will vary depending on the desired end result. The amount of carbonaceous material should be such that, when combusted, the carbonaceous material provides at least sufficient heat for carbonisation of the brown coal or peat and reduction of the zinc oxide and any other metal oxides which may be present.

Typically, step (c) of the inventive process is conducted in a furnace chamber. The reductant formed in step (c) of the inventive process reacts with zinc oxide in the composite bodies and reduces it to zinc. The reduction reaction largely takes place at the boiling point of zinc (907°C).

Accordingly, the vapourisation of zinc enables a relatively simple but effective means of separating zinc from other elements present in the zinc containing material, especially where that material comprises EAF dust. In the latter case, the boiling point of zinc is considerably lower than those of the other
5 metals of interest in the EAF dust, especially iron (3000°C) and lead (1515°C).

In step (d) of the inventive process, zinc vapour produced from the reduction reaction is collected and cooled to form zinc metal. Typically, the zinc vapour is directed into a condenser in which the vapour is cooled to form the zinc metal.

10 EAF dust and brown coal typically contain refractory materials, such as silica, alumina and calcium and magnesium oxides, as well as sulphur. To reduce or remove these impurities, the controlled addition of a fluxing agent, or its precursor, is highly desirable. The production of a basic slag is preferred in order for desulphurization reactions to occur. A suitable flux precursor is limestone or
15 magnesite.

The apparatus of the present invention includes a furnace chamber in which the reduction of the composite bodies takes place. The furnace chamber should be heatable to at least a temperature sufficient to convert at least some of the carbonaceous material to a combustible gas and to effect reduction of the zinc
20 oxide to zinc. Also preferably, the chamber includes a heat resistant container for location within the chamber, which container is used for receiving the composite bodies. In such an arrangement, a gas conduit preferably extends from the heat resistant container to a gas burner for heating the furnace. Once the heating means has heated the furnace and mixture of reactants to the required
25 temperature, carbon monoxide and other combustible gases are evolved from the reactants and pass through the gas conduit to the gas burner. The furnace

heating means and gas burner may be one and the same, or different features. Once evolution of the combustible gases commences, the gas burner may be lit and the heating means (if a separate feature) turned off. The gas burner can then be used to maintain the furnace temperature at the desired level.

5 An outlet is provided in a wall of the furnace chamber and a condenser is in communication with the furnace chamber via the outlet. Zinc vapour produced during the reduction process passes through the outlet and into the condenser where it is collected and cooled to form zinc metal. Typically, this requires the outlet to be in an upper region of the furnace chamber above the charge of
10 composite bodies.

 The condenser may be any suitable container in communication with the furnace outlet. The condenser is maintained at a temperature below the boiling point of zinc so that condensation of zinc may occur therein. However, the temperature of the condenser should not be too cool in order to avoid premature
15 solidification of zinc as fine grained metal, which can easily reoxidise upon exposure to air. Preferably, the condenser is maintained at a temperature from 400 to 700°C, more preferably between 500 and 600°C. The temperature is preferably controlled by providing adequate insulation of the condensation chamber, allowing the latent heat of condensation of zinc and the heat in the
20 waste gases to provide the desired heat. A "zinc splash condenser" may be employed and comprises a motorised rotor which splashes liquid zinc droplets into the path of the waste gas.

 Alternatively, the temperature of the condenser may be controlled by means of heating means, such as a furnace, preferably a muffle furnace in which
25 the condenser is positioned.

Preferably the condenser is manufactured from a heat and chemically resistant material, such as a refractory material, preferably a refractory ceramic. A suitable refractory material is fireclay.

The condenser preferably includes a main condenser chamber having an
5 inlet for receiving zinc vapour. The inlet is preferably positioned above the base of the main condenser chamber such that condensed zinc does not pass back into the furnace chamber. Preferably, the main condenser chamber surrounds a vapour conduit, the open end of which forms the vapour inlet, extending from the outlet of the furnace chamber to a region of the condenser above its base.

10 In one embodiment, the zinc condenser is positioned above the furnace chamber and the vapour conduit extends in a substantially vertical direction from the furnace outlet into an upper region of the condenser chamber. However, preferably the vapour conduit extends in a lateral direction from the furnace outlet into an upper region of the condenser chamber.

15 Where the zinc oxide containing material includes other elements apart from zinc, the process of the present invention is an effective means of separating zinc from those other elements. In the case of EAF dust, the process of the invention is able to effectively separate zinc from other metals, especially iron and lead.

20 In the embodiment of the invention dealing with EAF dust, the reductants formed from carbonaceous materials may also reduce other metal oxides, such as iron oxides and lead oxides, in the composite bodies. Such reduction processes may proceed in accordance with the metal reduction processes disclosed in Australian Patent No. 703821, the entire disclosure of which is incorporated
25 herein by reference. AU 703821 deals particularly with the reduction of iron oxides using reductants formed from carbonaceous material present in the

composite bodies. In that process, after reduction of the iron oxide, the temperature of the reduced composite bodies is increased by contacting the hot bodies with an oxygen-containing gas to combust sufficient remaining carbonaceous material so as to raise the temperature of the bodies to the melting temperature of iron (1535°C) to thereby form a molten metal phase. Accordingly, the carbonaceous material provides fuel for melting of the reduced metals, as well as providing reductant for reducing the metal oxide.

If necessary, the composite bodies may need to also include a flux material, especially where the EAF dust and/or carbonaceous material contain significant impurity levels. The flux forms a slag phase containing the impurities during melting of the metal. If flux is added to the composite, it can be either added separately, preferably in powder form, to the composite body, prior to melting the metal, or, it can be mixed with the zinc oxide containing material and carbonaceous material of step (a), such that the composite body subsequently formed is self-fluxing. Alternatively, a flux precursor, such as uncalcined limestone, can be added to the mixture in step (a). During reduction of the composite body subsequently formed, the flux precursor undergoes calcination to form the flux. In the case of uncalcined limestone, it undergoes calcination to form lime during the reduction step. Adding uncalcined limestone to the composite body is advantageous because uncalcined limestone is less expensive than lime, thus making the composite more economical to produce. The flux or flux precursor may comprise a calcium or magnesium oxide or hydroxide, or a carbonate such as limestone (CaCO_3) or magnesite (MgCO_3).

The molten metal phase which may be formed from using EAF dust in the inventive process includes metals other than molten iron, such as molten lead which has a relatively lower melting temperature of 327°C. Moreover, because

molten lead has a higher density than molten iron, molten lead occupies a lower level in the molten metal bath than molten iron. This feature enables separation of lead from iron, such as by tapping off molten lead via an outlet located below the lead/iron interface.

5 The apparatus of the present invention is advantageously based upon the design of a retort disclosed in WO01/348455, the entire disclosure of which is incorporated herein by reference. The retort of WO01/38455 included a thermally insulated casing defining a furnace chamber therein;

10 one or more columns provided within said chamber, each column comprising a plurality of vertically orientated, vertically spaced, heat resistant tubes, wherein the cross-sectional area of each tube is smaller than that of an adjacent, lower tube, and wherein the ends of adjacent tubes are arranged so as to provide an annular space therebetween,

15 an inlet through which a combustible charge is fed into the uppermost tube, an outlet from which reacted charge is removed from the lowermost tube; and

 a fluid conduit for conveying combustible volatiles evolved by heating said charge to a gas burning means for combustion, to thereby provide heat to said retort.

20 A key feature of the retort of WO01/38455 is the provision of one or more columns, each comprising a succession of vertically spaced heat resistant tubes located inside an internally insulated surrounding shell or casing. The casing is preferably made of steel, more preferably mild steel. The tubes themselves are typically made from a suitable heat and chemical resistant material, such as an alloy, which may contain steel. The distance between the columns of tubes and

25

the shell will vary but should be such as to provide adequate volume for efficient combustion of the heating medium used.

The retort may contain two or more laterally spaced columns, each comprising a succession of vertically spaced tubes, in order to increase the throughput of material treated in the retort.

Preferably the or each column includes three or more vertically orientated, substantially coaxial tubes. These are advantageously vertically spaced from each other such that there is partial overlap between adjacent ends, thereby defining an annular space therebetween. The annular space enables volatiles evolved during heating and/or reaction of the charge to escape therefrom. After the initial start up, combustible volatiles combust at the annuli, thereby providing heat for subsequent reaction of the charge, meaning that the external heating means can be turned down or off.

Preferably each vertical tube is suspended at an end thereof within the retort, allowing free discharge of the charge into the adjacent, lower vertical tube. Moreover free suspension of each tube and the absence of joins between tubes facilitates thermal expansion and contraction of the tubes and reduces failure due to thermal cycling.

The retort of WO01/38455 preferably comprises two or more combustion zones. A first combustion zone is typically located in an upper region of the retort and a second combustion zone is typically located in a lower region of the retort. Preferably the first and second combustion zones are separated by a wall, and together form a unitary body. More preferably, the wall supports one of the vertically orientated tubes which is suspended therefrom. Preferably, the first and second combustion zone each accommodate one or more vertical tubes, such that each combustion zone has an annulus between tubes opening therein. The

provision of more than one combustion zone is advantageous in that it enables greater control over the heating process, as will be subsequently discussed in further detail.

5 In the first combustion zone, the temperature of the charge is raised causing any free water and chemically fixed water to be evolved from the charge. With increasing temperature, low temperature coal volatiles are released (where the carbonaceous material is brown coal), then carbon dioxide is released from any carbonate breakdown. Finally high temperature coal volatiles are released.

10 In the second combustion zone, the temperature of the charge is raised to a value and for a time sufficient to effect the desired reaction, in the present case, the reduction of metal oxides to metal.

In the modified version of the retort employed in the present invention, a zinc condenser is provided in communication with the second combustion zone. Accordingly, zinc vapour released during reduction of zinc oxide in the second combustion zone exits the second zone via an outlet and passes via a vapour
15 conduit into a zinc condenser. Zinc metal is subsequently recovered from the condenser.

In one preferred embodiment, a gas burner is preferably provided near or at the top of the second combustion zone. Because combustion would take place
20 in the second combustion zone near the top thereof, combustion gas flow is in a generally downward direction. Accordingly zinc vapour produced in the second combustion zone is swept in a generally downward direction by the combustion gas flow and collects toward the base. The zinc vapour then exits the second combustion zone by flowing into the zinc vapour outlet, typically located near the
25 base of the second combustion zone, and travels to the zinc condenser via the vapour conduit. Preferably, the combustion conditions in at least the second

combustion zone are fuel rich in order to maintain a reducing atmosphere thereby minimising reoxidation of zinc vapour.

The modified retort also typically includes a melting zone, preferably provided by an integral metal melting unit, such as an induction furnace, which
5 communicates with the outlet of the reduction furnace chamber, such that the composite pellets are fed thereto after being reduced. Preferably, the melting unit is located vertically below the outlet of the furnace chamber such that the reduced pellets are automatically and continuously fed into the melting unit under gravity.

The melting unit preferably includes an insulated melting chamber for
10 receiving the reduced pellets. Once in the melting unit, the temperature of the reduced pellets is raised sufficiently to effect melting of the metal (and any slag phase, if present). This may be achieved by simple combustion of the carbonaceous material remaining in the reduced pellets, possibly aided by injection of an oxidising gas through pipes or tuyeres. If necessary, additional fuel
15 may also be added at this time, for example combustible gases and/or solid materials. Preferably, the oxidising gas is preheated, such as by heat exchange with waste gases from the retort, and typically comprises air or some other oxygen containing gas.

Advantageously, the temperature increase in the melting unit is augmented
20 by employing an external heating means. Preferably, the external heating means is an electrical heating means, such as an induction heater, resistance heater or a submerged arc. An induction heater is particularly preferred. In the case of an induction heater, the wall of the insulated melting chamber typically accommodates a conductor coil, with the metal to be melted forming the
25 secondary of a transformer. An induction heater can be used alone or in conjunction with the oxidising gas assisted combustion.

Without wishing to be limited to a particular reaction mechanism it is believed that while some of the zinc produced from the reduction reaction exits the reduction zone as zinc vapour, substantial quantities re-condense to liquid zinc, with the latent heat of condensation being absorbed by the endothermic reduction reactions. This is clearly problematical because the re-condensed zinc must be boiled off before the temperature of the reduced pellets can be increased, in order to melt the remaining metals in the pellets (and any slag phase, if present). This typically requires that the temperature of the "zinc boiling zone", located above the melting zone of the pellet charge, be maintained sufficiently high to provide the latent heat of vaporisation of zinc. This may be provided either by a separate heating means, or by ensuring that sufficient waste gas flows from the melting zone into the boiling zone, or both.

The required flow of waste gas can be supplied in a number of possible ways, examples are:

1. Combustion of excess carbon in the reduced pellets with air to form carbon monoxide and nitrogen.
2. Combustion of solid, liquid or gaseous fuel with air to form carbon monoxide, water vapour and nitrogen.
3. Injection of flux precursors (e.g. limestone) into the melting zone. Carbon dioxide from calcination of the flux precursor then reacts with excess carbon from the reduced pellets and/or added fuel to form carbon monoxide.
4. Injection of inert gas.
5. A combination of two or more of the above.

It is important that no free oxygen is allowed to enter the zinc boiling zone as reoxidation of zinc can occur.

The melting unit of the modified retort includes at least two, and preferably three outlets. A first outlet is located near or at the base of the melting unit for discharge of molten lead. A second outlet is located higher than the first outlet and is for the discharge of molten iron. A third outlet (if present) is located higher than both the first and second outlets and is for the discharge of a slag phase.

In a particularly preferred embodiment of the modified retort of the invention, a heatable conduit (e.g. a cast iron pipe wound with electrical heating tape) extends from the first outlet to a lead collection means where molten lead is discharged and collected. The discharge end of the lead conduit is elevated relative to the first outlet. Lead is allowed to solidify in the heatable conduit, thereby sealing the conduit until required. When sufficient lead has accumulated in the molten metal bath, the heatable conduit is heated to a temperature at least equal to the melting point of lead, at which time, the lead in the lower part of the melt bath will flow through the lead conduit to the lead collection means until the static head of lead equals the static head of molten metal in the bath. At that time, the heatable conduit is cooled, thereby resolidifying the lead in the conduit and stopping lead flow.

The following Examples and drawings illustrate, in detail, embodiments of the invention, but they are not intended to restrict its scope.

Examples 1 and 2

Example 1

Electric Arc Furnace (EAF) dust as collected in a bag filter was wetted with a small amount of water and formed into pellets in a disc pelletiser. Pelletisation of EAF dust, while not necessary to the process of the invention, renders the dust easier to handle and store.

The EAF pellets were then mixed with wet brown coal, in equal quantities, plus additional water (if necessary) and subjected to attritioning and extrusion to produce substantially homogeneous pellets. The extruded pellets were then dried, either naturally by placing them on trays on covered open racks exposed to ambient air, or by force drying by application of some heat.

One embodiment of apparatus used for carrying out the process of the invention is illustrated in Figure 1. A first muffle furnace 10 has located therein a stainless steel container 12, acting as a retort, in which are placed the EAF-brown coal composite pellets 14. A first thermocouple 16 monitors the temperature of the pellets 14 while they are being heated.

The recessed lid 18 of the muffle furnace 10 has an outlet 20 provided centrally therein and a conduit 22 leading from the outlet 20 away from the interior of the muffle furnace 10. Zinc vapour, and other volatiles and gases, are discharged from the first muffle furnace via the outlet and conduit. On the underside of the recessed lid 18 is provided an annular ceramic heat shield 23, the purpose of which is to prevent zinc from condensing on the underside of retort lid 18.

Surrounding the conduit 22 and located within the recessed lid 18 is a zinc condenser 24 comprising a condenser chamber 26 and vertical, integral vent pipe 28, leading away from the condenser chamber 26. The zinc condenser 24 is formed from fireclay, although other refractory materials may instead be used.

Surrounding the zinc condenser 24 and located above the first muffle furnace 10 is a second heating means comprising a second muffle furnace 30. A second thermocouple 32 is provided within the second muffle furnace 30 in order to monitor the interior temperature therein. The purpose of the second muffle furnace is to maintain the temperature of the zinc condenser 24 in the preferred

range of 500-600°C, so as to avoid the premature condensation of zinc as a fine dust and instead allow collection of zinc as a bulk liquid phase. Furthermore, the second muffle furnace 30 serves to burn any coal volatiles and reduction gases emitted from the first furnace before their release.

5 Accordingly, in use, the EAF-brown coal pellets 14 are heated in the first muffle furnace 10 to the reduction temperature. Reduced zinc oxide, in the form of gaseous zinc, is discharged from the pellet charge at temperatures in excess of 907°C, and exits the first muffle furnace 10 via the outlet 20 in the recessed lid 18. The zinc vapour travels via conduit 22 into the zinc condenser 24. The zinc
10 vapour condenses into zinc metal, shown as reference numeral 34 in Figure 1, in the bottom of the condenser chamber 26. Waste gases are discharged into the interior of the second muffle furnace via the vent pipe 28.

 Upon completion of the reduction of the pellets 14, the condenser 24 is removed from the second muffle furnace and cooled. The condenser was found
15 to contain a substantial quantity of zinc. The substantially zinc free reduced pellets in the first muffle furnace were transferred to a preheated crucible and a small amount of oxygen was injected. This caused the pellets to melt, and upon cooling they separated into an iron phase and a slag phase.

 Samples of the EAF-brown coal pellets, iron slag and zinc phases were
20 analysed and the results are presented in Table 1.

 There was virtually no zinc in the iron or the slag. The lead in the zinc represented less than 3% of the lead in the feed pellets, . There were no significant amounts of lead in the iron or the slag.

Example 2

25 In Example 2, the process of Example 1 was repeated and the zinc recovered was analysed. The results are presented in Table 2.

Example 3

A second embodiment of the apparatus according to the invention is illustrated in Figure 2. A retort 150 includes a thermally insulated metal shell or casing 152 defining therein an annular furnace chamber 154. The furnace chamber 154 houses a column 155 of heat resistant tubes 156, 158, 160 and 162 which are vertically orientated and vertically spaced from each other. The cross-sectional area of the tubes 156, 158, 160 and 162 increases in going from the top of the retort 150 to its bottom. Accordingly, the relative cross-sectional area of the tubes is as follows tube 156 < tube 158 < tube 160 < tube 162.

The respective ends of adjacent tubes overlap to thereby form open annular spaces 164, 166, 168 therebetween.

The uppermost tube 156 includes an inlet 157 and acts as a feeder tube through which the pellet charge material 169 is fed into the retort 150. The charge moves through the tubes 156, 158, 160 and 162 in succession under the force of gravity. An outlet 170 is provided at the bottom of the lowermost tube 162 through which the reacted charge 169 leaves the retort 150.

The furnace chamber 154 is divided into first and second combustion zones comprising first and second chambers 154a and 154b respectively, by a transverse wall 174. The combustion chambers 154a and 154b each include a heating means comprising a gas burner 171, 172 respectively which provide an initial heat source for raising the temperature of the charge 169. The gas burner 172 in the combustion zone 154b is larger than burner 171 in order to provide sufficient heat for commencement of combustion. Furthermore, the gas burner 172 is located near the top of chamber 154b, whereas gas burner 171 is located near the bottom of chamber 154a.

A fluid conduit 176 extends from the top of chamber 154a to the top of chamber 154b. Gases evolved from heating the charge 169 are evolved from open annuli 166 and 164 and travel through the conduit 176 to the chamber 154b, where they are combusted. Because combustion in chamber 154b occurs near the top thereof, combustion gas flow will be in a generally downward direction. Accordingly, any zinc vapour produced in chamber 154b is swept downwards by the combustion gas flow and collects at the base of chamber 154b. The zinc vapour then exits chamber 154b by overflowing into conduit 180, located near the base of chamber 154b, and travels to a zinc condenser 124. The combustion conditions in both chambers 154a and 154b are operated fuel rich so as to maintain a reducing atmosphere in both chambers thereby minimising reoxidation of zinc vapour.

The retort 150 further includes a third combustion chamber 178 communicating with the second combustion chamber 154b via the conduit 180 and the zinc condenser 124. The third combustion chamber 178 in turn communicates with a recuperator 182 through which exhaust gases pass to exhaust outlet 184 under operation of an exhaust fan 185. A gas burner 183 is provided inside the third combustion chamber 178.

The recuperator 182 includes a conduit 186 through which passes atmospheric air admitted through inlet 189 under action of a fan 193, and an outlet 187 through which preheated air exits. In the recuperator 182, the heat from the exhaust gases is transferred to the incoming air to thereby preheat it and the preheated air enters the first and second chambers 154a and 154b via fluid conduits 188 and 190, respectively. Fluid conduit 190 enters chamber 154b near its top where gas burner 172 is located. The amount of air flowing into the chambers 154a and 154b can be regulated by dampers 192, 194 respectively.

At the base of retort 150 is provided a metal melting unit comprising an induction heater 196. The reduced pellets are fed under gravity into the induction heater 196 via the retort outlet 170. The induction heater 196 includes an upper, slag outlet 198 and a lower, molten metal outlet 200. The slag outlet 198 is located at an upper region of the induction heater 196 and the metal outlet 200 is located at a lower region. In use, once the reduced charge is melted in the induction heater 196, any slag phase which forms on top of the molten metal phase is tapped off via the slag outlet 198. The molten metal, typically carbon rich iron, is tapped off via molten metal outlet 200. Both the slag and metal outlets 198, 200 can be closed by removable, moist fireclay plugs.

At the base of the induction heater 196 is a second molten metal outlet 202 through which molten lead may be tapped off. Molten lead is denser than molten iron and therefore tends to accumulate towards the base of the induction heater.

A modification of the second molten metal outlet is shown in Figure 3. The second molten metal outlet 302 feeds to a heatable conduit 304 comprising an insulated cast iron pipe 306 having electrical heating tape 308 wound therearound. The exit 311 of the cast iron pipe 306 is positioned above the outlet 302 of the induction furnace 296. A lead mould 313 collects the molten lead discharged from the induction heater 296.

The operation of the molten metal outlet 302 will now be described. Prior to the first use, the iron pipe 306 is sealed with a plug of solid lead. When a predetermined amount of molten lead has accumulated in the base of the induction furnace 296 (determined from the mass of pellets reduced) the heating tape 308 is switched on, thereby melting the lead plug therein and enabling molten lead to flow from the induction heater 296 into the heatable conduit 304. Molten lead will flow from the exit 311 into the lead mould 313 until the static head

in the pipe 306 balances the static head of molten metal in the induction heater 296. In this manner, the flow of lead can be controlled and discharge of molten iron through the molten metal outlet 302 avoided.

Example 4

5 A modification of the second combustion chamber and induction heater at the base of the retort is illustrated in Figure 4.

 In Figure 4, like reference numerals relate to the corresponding parts of Figure 2. The base of the second combustion chamber 454b is funnel-shaped and in effect forms an integral lower-most tube 462 (the functional equivalent of
10 lower-most tube 162 of Figure 2). The top of the induction heater 496 has also been modified to receive a gas burner 515 through an opening therein 517. In addition, further fuel, preheated air, flux precursor (e.g. limestone) and/or oxygen may be admitted through the opening 517, in order to produce sufficient hot waste gas for heat transfer. Typically, a temperature of at least 1500°C will be required
15 in the "melting zone" located towards the top of the induction heater 496, in order to ensure sufficient heat transfer that the "zinc boiling zone", towards the base of the second combustion chamber, is maintained at a temperature of 907°C or higher. Accordingly, zinc vapour released from the zinc boiling zone exits the second combustion chamber 454b via conduit 480 and travels to the zinc
20 condenser (not shown).

 Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts and

steps previously described without departing from the spirit or ambit of the invention.

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TABLE 1

		Feed Pellets	Slag	Iron	Zinc
Weight	gms	4,360	283	418	295
Water	H ₂ O	13.2			
Silica	SiO ₂	1.76	20.2		
Alumina	Al ₂ O ₃	0.37	22.9		
Iron Oxide	Fe ₂ O ₃	20.3	5.15		
Chromium Oxide	CrO ₃	0.15	0.45		
Calcium Oxide	CaO	4.36	30.5		
Magnesium Oxide	MgO	1.77	12.1		
Sodium Oxide	Na ₂ O	1.57	1.81		
Potassium Oxide	K ₂ O	0.79	0.10		
Manganese Oxide	MnO	1.57	7.31		
Titanium Oxide	TiO ₂	0.04	0.27		
Phosphorous Pentoxide	P ₂ O ₅	0.09	0.12		
Zinc Oxide	ZnO	22.7			
Lead Oxide	PbO	1.48			
Carbon	C	19.4	0.08	2.1	
Sulphur	S	0.16	3.8	0.13	
Manganese	Mn			1.9	
Silicon	Si			2.1	
Phosphorous	P			0.24	
Nickel	Ni			0.11	
Chromium	Cr			0.30	
Molybdenum	Mo			0.02	
Copper	Cu			0.70	
Iron	Fe			92.4	0.006
Lead	Pb				0.21
Zinc	Zn				99.8

TABLE 2

Zinc	Zn	99.8%
Lead	Pb	0.15%
Iron	Fe	0.008%

FIGURE 1

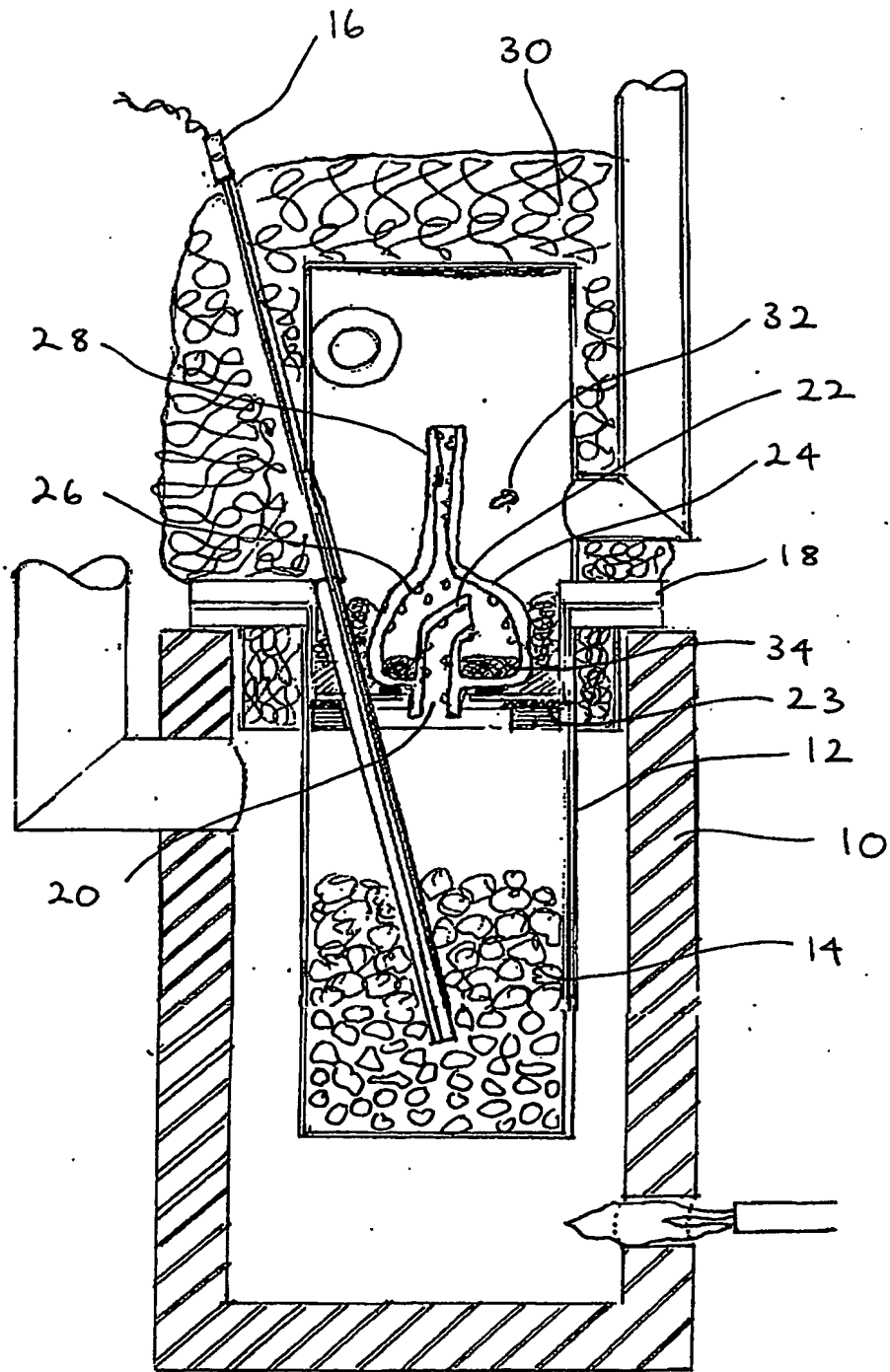


FIGURE 2

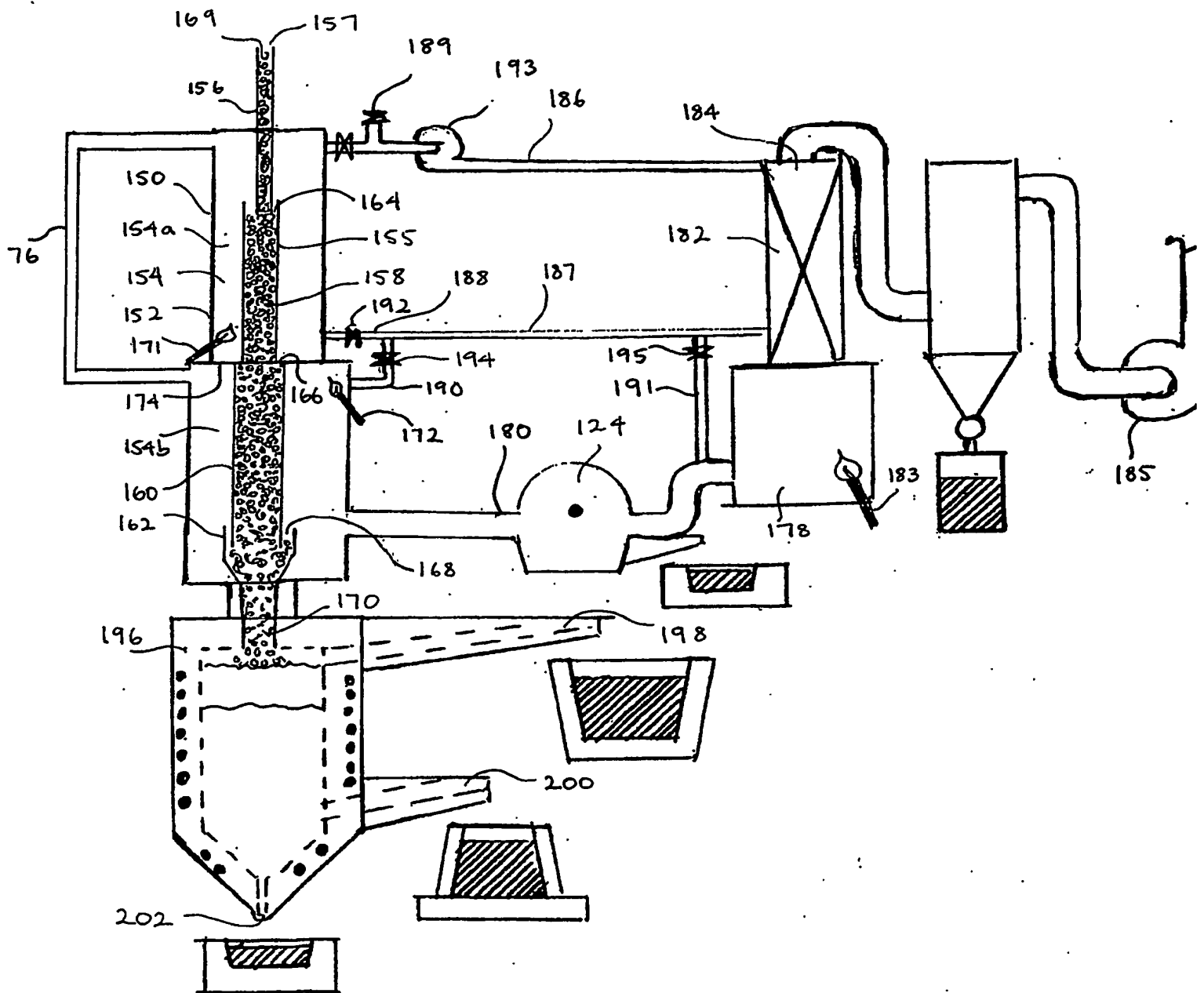
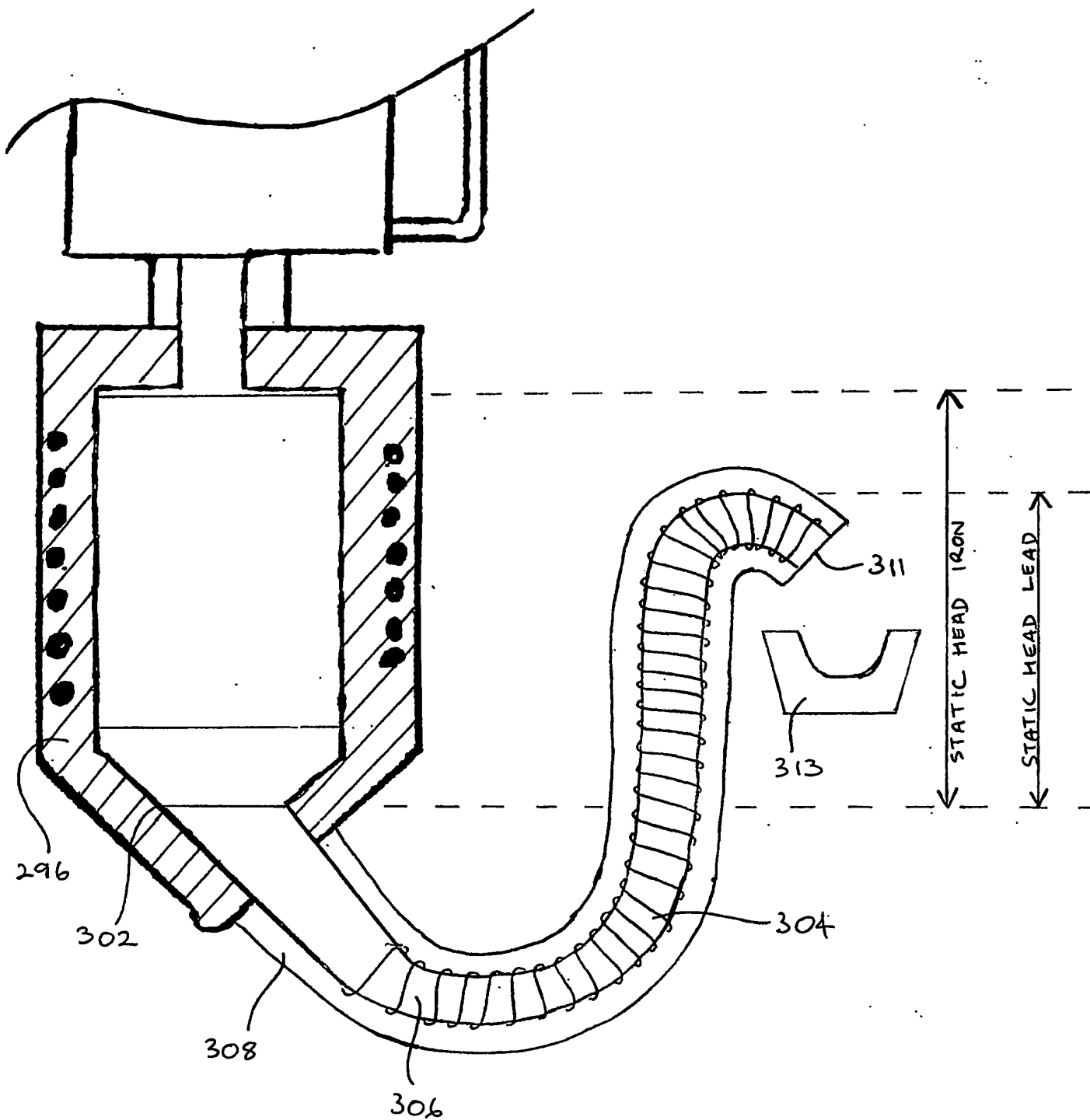


FIGURE 3



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FIGURE 4

